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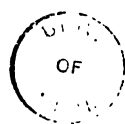
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BULLETIN OF
PURDUE UNIVERSITY

PUBLICATIONS OF THE ENGINEERING DEPARTMENTS

VOL. VIII

SEPTEMBER, 1924

NO. 10

**Operation of Three Phase
Induction Motors Under Abnormal
Supply Conditions**

BY

D. D. EWING

AND

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CIRCULAR NO. 4 (61)
ENGINEERING EXTENSION SERVICE
LAFAYETTE, INDIANA

Published by Purdue University at LaFayette, Indiana
Entered at the Post Office at LaFayette as second class matter under
the Act of July 16, 1894

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OPERATION OF THREE-PHASE INDUCTION MOTORS UNDER ABNORMAL SUPPLY CONDITIONS

By

D. D. EWING AND C. F. BOWMAN

The results of some tests in which three-phase induction motors were operated under conditions differing from those for which the motors were rated are described in this circular. The test conditions used were those which frequently occur in actual motor operation.

This circular presents in a brief way some operating data secured by operating commercial three-phase induction motors under service supply conditions other than those for which the motors were rated by their makers. The abnormal conditions used in these tests were those most likely to occur in a modern industrial installation.

Motor name-plate ratings as they apply to three-phase induction motors assume a three-phase, constant voltage and constant frequency supply. In practical motor installations these conditions are more likely to be the exception rather than the rule; the nominal 220-volt line may have a line-to-line voltage ranging from 180 to 250 volts and if the line carries a heavy, short-interval peak load this range may be covered within the time interval of twenty-four hours; the voltages may be badly unbalanced; the actual value of the nominal 60-cycle frequency is likely to be anything from 55 to 65 cycles; also, one of the three lines to a motor may be opened accidentally, thus allowing the motor to operate single-phase.

While the performance of a motor operating under other than rated conditions of supply may be predicted from theoretical considerations, practical operating tests are productive of results which, to say the least, are more convincing. Three series of such tests have been made on commercial motors; the first, that of single-phase operation, was made by C. W. Davis, R. H. Turner and A. J. Yauger. The other two series involving abnormal voltage and frequency were conducted by R. E. Payne, C. D. Gwinn, and R. C. Laney. All of these men were members of the 1924 Class in Electrical Engineering at Purdue University, and the tests were made in connection with their undergraduate thesis work.

Single-Phase Operation

A three-phase motor connected to a single phase circuit is not self-starting, but once started it will continue to run. Information relative to this kind of abnormal operation is important to users of this type of motor because when motors are so operated they cannot carry their rated loads without excessive heating.

Single-phase operation is ordinarily the result of the accidental opening of one of the lines to the motor. In some types of starting equipment the protecting fuses are shunted during the starting period and are in circuit only when the starter is thrown to the running position. Should one of the fuses be "blown", the motor will start normally and will continue to run when the starter is thrown to the running position, but it will be operating as a single-phase motor. If the load is considerably below the rating of the motor, the motor may continue to operate in this fashion for months before the fault is discovered unless rigid inspection routines are maintained. Another common cause of single-phase operation is the burning off or loosening of the fingers or contacts on the running side of the starter. As the contacts are out of sight in the starter box or immersed in oil, this fault also may remain undiscovered for some time. One of the authors in making a survey of a woodworking plant discovered that two out of six large group-drive motors were operating single-phase and no one about the plant had the slightest idea as to how long they had been operating in this manner. The motors were running warm and the survey was being made because the management was proposing to install new and larger motors.

It is not always easy to detect single-phase operation except by making tests with instruments. Unusual vibration and excessive heating are two of the most common symptoms. Periodic inspection of the motors and their wiring and protective equipment is the best preventive.

Table I sets forth the more important descriptive data pertaining to the motors tested for single-phase operating performance. In these tests the motors were supplied from a motor-generator set which enabled the voltage and frequency to be maintained constant. Each motor was operated three-phase and the load on it adjusted until the motor drew rated current. The load was then maintained constant until thermometers, placed on the motor windings at various places to indicate temperature rise, showed constant temperature. The motor was then allowed to cool down slightly and one of the line wires was opened, causing the motor to operate as a single-phase motor. The load was then adjusted to give the same temperature rise as occurred with three-phase operation.

In Table II are shown the results of this test. It will be noted that the horse-power output for rated current, three-phase operation, agreed closely with the horse-power ratings given by the makers in Table I. The single-phase output has a mean value, as shown by Table II, of about 50 per cent of the three-phase output and the single-phase current per terminal for this output is approximately 20 per cent in excess of the three-phase rated current per terminal.

TABLE I.—Descriptions of the Motors Operated Single-Phase.

Motor Number.	A	B	C	D	E	F
Rated Horsepower	7.5	5.0	7.5	5.0	3.0	1.0
Rated Voltage	110	110	110	110	110	110
Rated Amperes per Terminal	37.3	28.2	37.5	29.6	16.3	6.0
Rated Speed	1700	1200*	1760	1750	1750	1700
Frequency	60	60	60	60	60	60
Guaranteed Temp-Rise Deg. C.			50	50	50	50
Type of rotor	Squirrel Cage	Wound Rotor	Squirrel Cage	Wound Rotor	Squirrel Cage	Squirrel Cage

* Synchronous Speed.

TABLE II.—Results from Single-Phase Tests.

Motor Number	A	B	C	D	E	F
Horsepower—Three phase	7.45	5.08	7.23	5.12	2.89	.95
Horsepower—Single phase	4.25	2.60	4.06	2.50	1.66	.42
Amperes per terminal, Single phase	43.0	32.0	45.5	35.0	20.5	6.8
Ratio, single-phase current to three-phase current	1.15	1.14	1.21	1.18	1.26	1.13
Ratio, single-phase horsepower to three-phase horsepower	.57	.51	.56	.49	.57	.44

These data show that for lightly loaded motors single-phase operation over a long period of time is not likely to injure the motor. On the other hand, motors which are located in warm rooms and on which the mean load is in excess of 50 per cent of the rating are very likely to be seriously damaged by prolonged single-phase operation.

Motor Operation at Voltages and Frequencies Other Than Rated

Manufacturers of motors and generating machinery have standardized certain voltages and frequencies and their regular lines of equipment conform to these standards. It is not the purpose here to enter into an extended discussion as to why supply voltages and frequencies other than standard exist. Suffice it to say that owing to local conditions such variations from standard values are extremely common. Only in large cities is it possible ordinarily to furnish service of such high class that the voltage and frequency will conform closely to the nominal standards. In small communities the cost of furnishing such service is so high as to make it impracticable.

To determine the performance of commercial motors when operated under other than rated voltage and frequency conditions, tests were run on the motors described in Table III. In making these tests the motors were all supplied from the same motor-generator set. The voltage and frequency of this set could be adjusted and the

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